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CHOICE OF FUEL FOR BAGACO STILLS HELPS MAINTAIN BIOLOGICAL DIVERSITY IN A TRADITIONAL PORTUGUESE AGRICULTURAL SYSTEM

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ABSTRACT.—The present vegetation on the shale hills of central interior Portugal is called *mato*. It consists of shrubs mostly in the heath (Ericaceae) and bean (Fabaceae) families. Farmers in this region harvest *mato* and, whenever they plant a crop, bury it in their cultivated plots to make the soil fertile. Farmers cut *mato* at ground level, leaving the woody root crown (caudex) just at ground level. *Mato* plants regrow from these caudices. They are harvested again every four years. In addition, the woody caudex of primarily one species, *Erica arborea*, is occasionally dug up and burned to distill a brandy-like liquid, called *bagaco*, from the mass of grape skins, seeds, and pulp that is left over after the fermented wine is drawn off. Interviewing and observing farmers revealed important uses of many different *mato* species. Sampling *mato* vegetation from areas regenerating from four to 30 years showed that *E. arborea* is competitively dominant and capable of reducing *mato* species diversity. The slow, cool burning qualities of any caudex would be adequate for a still fire, and farmers occasionally do use different species for this. However, the practice of occasionally removing the caudex of the competitive dominant for still fires serves to maintain the variety of useful species in the *mato*. The somewhat unfounded explanation that *E. arborea* caudex is best for still fires results every fall in appropriate and timely activity, and as such may serve better than would a more ecological, long-term explanation for the same practice.

RESUMO.—O mato natural das formaçōes xistosas do centro interior de Portugal é formado por arbustos principalmente das famílias Ericaceae e Fabaceae. Os agricultores daquela regiāo cortam o mato e, sempre que fazem uma nova cultura, enterram-no nas suas hortas para melhorar a fertilidade do solo. Os agricultores cortam o mato rente à superficie da terra, deixando assim as suas raizes lenhosas logo abaixo da superficie. O mato regenera-se a partir dessas raízes e é cortado de novo todos os quatro anos. Contudo, também as raízes lenhosas de *Erica arborea* sāo por vézes arrancadas e queimadas na distilaçāo do bagaço. Foram identificadas várias utilizaçōes importantes de muitas espécies diferentes de mato. A amostragem da vegetaçāo do mato das áreas em regeneraçāo durante quatro, oito, e trinta anos mostrou que a *Erica arborea* é a dominante competitiva e é capaz de reduzir a diversidade das espécies no mato. Embora para um fogo de destilacao sejam adequadas as características de queima lenta e de baixa temperatura de qualquer raiz, a prática existente de arrancar as raízes só da dominante competetiva para queimar serve também para manter no mato a diversidade de especies úteis. A preferência de certa forma arbitrária pela queima da raiz da *E. arborea* em fogo lento proporciona faz cada outono uma lembrança temporal para uma atividade apropriada e desta forma pode servir melhor do que uma de longo têrmo, mais ecológoca.

RÉSUMÉ.—La végétation naturelle du mato des collines de schiste du centre intérieur du Portugal consiste d'arbustes, dont la plupart font partie des familles Ericaceae et Fabaceae. Les agriculteurs de cette région moissonnent le mato et, quand ils sement une nouvelle culture, ils en enterrent de grandes quantités pour engraisser le terrain. Les agriculteurs coupent le mato à quelques centimètres au dessus du sol, en laissant les racines épaisses et ligneuses juste en dessous du sol, desquelles poussent de minuscules racines qui s'enfoncent dans la pierre pour des dizaines de mètres afin de faire monter des éléments nutrifs et de l'eau. Le mato repousse de ses racines épaisses et ligneuses et est moissoné de nouveau tous les quatre ans. Parfois, les racines d'une espèce, *Erica arborea,* sont arrachées et brûlées pour la distillation du bagaco. Des entrevues avec des agriculteurs et des observations des agriculteurs ont révélé de divers usages importants de plusieurs espèces de mato. La végétation mato des locaux de quatre, huit, et trente ans de régénération a démontré que *E. arborea* est le dominateur compétitif et est capable d'abaisser la diversité d'espèces dans la végétation mato. Bien que les racines ligneuses de n'importe quelle espèce de mato pourraient servir à faire un feu de distillation parce qu'elles brûlent lentement et pas trop fort, le fait qu'on n'arrache que les racines du *E. arborea* pour cet usage sert à maintentir la diversité d'espèces utiles du mato.

INTRODUCTION

An important reason to study a traditional agricultural system where it has supported a population for hundreds of years is to try to determine, from an ecological point of view, how various aspects of its technology contribute not only to the productivity but also to the sustainability of the system. Because traditional agricultural technology is usually developed empirically over generations, ecological explanations for some of the very specific, but seemingly arbitrary, practices are not always apparent in the oral tradition of the contemporary population, especially when these practices are more related to long-term sustainability than to short-term productivity. It is remarkable how the persistent empiricism of human beings, struggling to make their living in nature, results in practices that make ecological sense, even though they may be codified in ritual or explained in ways that seem superficial or not compelling ecologically. Indeed, local practitioners may have concepts, equally justifiable but very different from those of academics, of what constitutes a useful explanation. This study of a traditional Portuguese agricultural system provides several examples, one of which is an ecological explanation for what initially seemed an arbitrary but nonetheless very specific fuel choice for the brief annual task of distilling a brandy-like liquid, called *bagaco,* from the mass of grape skins, seeds, and pulp that is left over after wine has been made.

In rural villages in Portugal, grapes are harvested in the fall and made into wine. After the fermented wine has been drained from the fermenting vat and casked, alcohol is distilled from the leftover grape skins and pulp by heating them gently over a cool fire. The distillate, called *bagaco* in some regions, is about 40% ethanol and 60% water, plus traces of higher alcohols and impurities. A little of it is drunk, but traditionally most of it is used as a household chemical for treating minor injuries, sterilizing, and cleaning.

The western and southern foothills of the Serra da Estrela (Fig. 1.), the highest range of mountains in Portugal, are made predominantly of Precambrian shale, with occasional quartzite intrusions. This shale easily erodes, producing very infertile clay soil of resedimented ilites high in iron and with low available water capacity (Azevedo and Ricardo 1973), and also producing very deep, steep-sided valleys that alternate with these quartzite peaks and ridges. Paths over the steep, crumbly rock offer poor footing. There is little or no rain in the summer months when temperatures often exceed 30° C. During the winter, temperatures are near 0° C at dawn, rising to near 15° C during the day. Frequent rains raise impassible torrents in the valley bottoms and erode from the hillsides what little soil may have accumulated during the past year.

Human beings have been culturally and economically active in Portugal for thousands of years. However, low overall population densities before the sixteenth century, abundant nearby land that is more level and fertile, the harshness and infertility of these foothills, and the establishment there of Catholic church parishes not before the fourteenth and fifteenth centuries, together suggest that this area had remained largely unoccupied until the fourteenth or fifteenth centuries. Although a discussion of the biological, social, political, and economic factors that may have motivated people to attempt to inhabit this region in the fourteenth century are beyond the scope of the work reported here, it seems plausible that many of the current practices directly observed in this study are based on techniques that have enabled people to inhabit successfully this harsh and infertile area since the fifteenth century. These techniques, and the self-sufficient village economies they supported, have largely disappeared from Portugal now. Refer to Pearson et al. (1987) for discussions of traditional Portuguese agricultural technology, and of the recent social, political, economic, and technological changes that have contributed to its disappearance.

All the details of the agricultural technology that enabled people to thrive in this marginal environment are beyond the scope of the work presented here, but a brief overview of the techniques used to create and maintain soil fertility is relevant. Cultivation of crops occurs on the steep hillsides in narrow terraces that are constructed of dry stone walls that hold the soil level. In winter, these terraces collect soil and water from above and help control water erosion. In the dry summer they facilitate irrigation by streams of water that trickle from slightly rising caves that have been dug above them about 10 m into the soft shale rock, where the shale is still wet from the rains of the past winter. To create fertility in the infertile clay soil in these terraces, large quantities of organic matter are collected, as brush from the hill tops, and mixed with the soil.

Shrubs, mostly heaths and legumes, make up the scrubby vegetation type called *mato,* which occurs in central-interior Portugal on the tops and upper slopes of shale hills. The *mato* on any given place is cut near ground level every four years. *Mato* is cut from somewhere, two or three times a week, all year long, and removed to the village, where it is spread over the floor of indoor, ground level rooms that house goats. After two to four weeks, this old *mato* is removed and replaced with freshly cut *mato.* After its removal, the old cut *mato* is piled up,

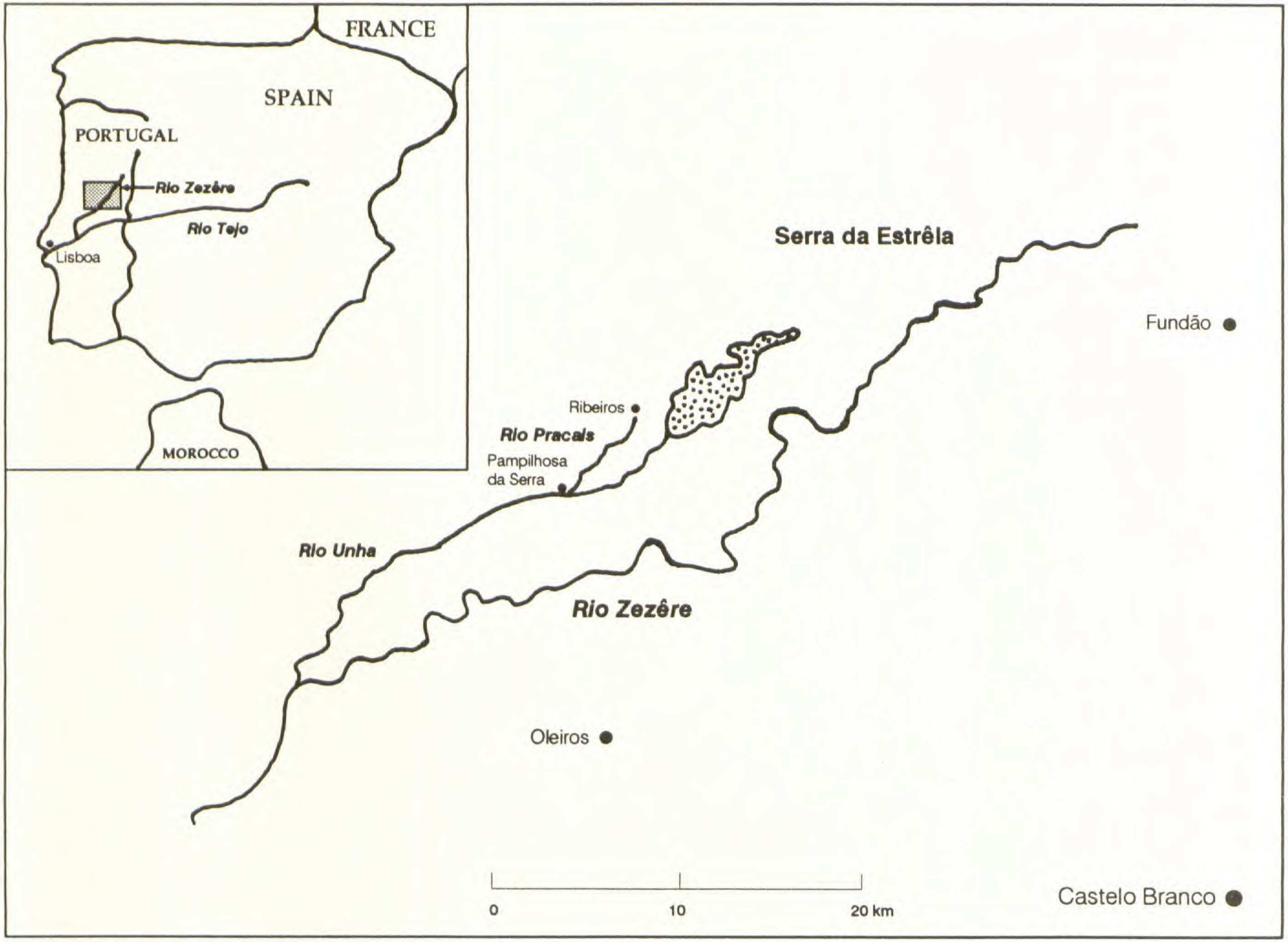

FIG. 1.—Map showing the location of the village of Ribeiros, at the headwaters of the Rio Pracais in the southwest foothills of the Serra da Estrela, Portugal. At the town of Pampilhosa da Serra, The Rio Pracais meets the Rio Unha, a tributary of Rio Zezere in the Rio Tejo drainage. The stippled area is an empoundment. Region of map is approximately the rectangle shown on the inserted outline of Iberia.

TABLE 1.—Principle *mato* species of the region studied.

Scientific name	Common name	Family	Collector Number[1]
Erica arborea L.	*mato negral*	Ericaceae	404
Ulex minor Roth	*tojo branco*	Fabaceae	407
Genista tricanthos Brot.	*tojo negro*	Fabaceae	406
Erica cinerea L.	*urze*	Ericaceae	403
Halimium ocymoidies (Lam.) Wilk. in Wilk & Lange	unknown	Cistaceae	408
Lithodora diffusa (Lag.) I.M.Johnson	unknown	Boraginaceae	401
Caluna vulgaris (L.) Hull	*margarise*	Ericaceae	405
Erica umbellata L.	*negrela*	Ericaceae	402
Chamaespartum tridentatum (L.) P. Gibbs	*carqueja*	Ericaceae	400

[1]All voucher specimens were collected by G. F. Estabrook and are housed at MICH.

and at planting time, buried in the soil of the cultivated terraces. Cut *mato*, enriched by goats, is the source of virtually all soil-borne plant nutrients, and much of the soil's available water capacity.

After a plant is cut, it regenerates from a woody root crown (caudex) just below the ground surface. These caudices ramify into an extensive system of fine roots, which penetrate for meters into the soft shale rock below. Although virtually all *mato* species regenerate in this way, the woody caudex of essentially only one, *Erica arborea*, is dug out and burned to distill *bagaco*. The caudex of *E. arborea* burns cool and slow, thus distilling the *bagaco* with a minimum of impurities and water. Pine *(Pinus pinaster)*, used inside the houses for cooking and warmth, would burn too hot, but any of the woody caudices of the *mato* species would burn cool and slow. Although the caudices of other mato species *are* occasionally used in conjunction with *E. arborea*, farmers clearly prefer *E. arborea* for still fires. Why principally just this one? They stated that it was used by their parents and grandparents, and that it is the best fuel for this task, but they never offered an explicit, functional or ecological explanation for their preference over other "roots."

Most of the principal *mato* species (Table 1) make distinct contributions, which this study will describe, to soil fertility and to other aspects of the local economy. Therefore, the maintenance of the species diversity of the *mato* is an important objective of this agricultural system. This study will also present species abundance data from plots of *mato* regenerating for differing numbers of years and subjected to different harvesting histories. These data show that *Erica arborea*, if not held in check, becomes the dominant species, and thus reduces species richness and diversity in the *mato*. The choice of the regeneration organ (the caudex) of *E. arborea* as a still fuel eliminates the domination of this species. Elimination of dominance maintains the species diversity in the *mato*, which contributes to the sustainability of this self-sufficient village economy. Grime

(1979) discusses in more detail competitive dominance and disturbance-mediated co-existence in stress tolerant plants.

It takes 9–10 ha of regenerating *mato* to supply enough organic matter to create fertility in 1 ha of cultivated terrace. It seems likely that the availability of *mato* may have begun to limit the amount of terrace under cultivation by the beginning of the nineteenth century or earlier. In this situation, all *mato* would have been managed for soil fertility, and thus cut every three or four years. Once the practice of removing a few *Erica arborea* caudices each fall was established, the potential for *E. arborea* to reduce or eliminate other valuable species would no longer be directly observed by the villagers. In the absence of these direct observations, a reason to remove every fall a few *E. arborea* caudices to burn in the brief task of distilling *bagaco* would ensure that the practice happened every year, and thus might serve the local economy better than would a more objectively founded, ecological explanation that did not require a specific action at a specific time.

MATERIALS AND METHODS

The principle area studied is the village group of Ribeiros, located in the Freguesia de Cabril, Concelho de Pampilhosa da Serra, Distrito de Coimbra, Portugal, at about north 40° 06' by west 7° 54'. The village is located near the center of this region of eroded shale foothills, among the branching streamlets (called *ribeiros,* hence the name) at the headwaters of the Rio Pracais, a stream that runs down a deep, steep-sided gully to the Unha river in the Rio Tejo drainage, as shown in Fig. 1. The elevation of the village is 750 m, with the hill tops and ridges rising 100–300 m above the village. Ribeiros is the modern name of the coalescence of three original settlements (Sobralinho, Melho, and Sanguasuga, located about 1 km apart but separated by deep stream gullies), which, judging from church records, was probably established in the late sixteenth century. It continued to grow steadily, and thrived in the nineteenth and first half of the twentieth centuries, reaching a population peak of approximately 300 in 1940, when the first road capable of carrying a motorized vehicle was built into the area to construct an empoundment (Fig. 1) to generate electric power. By the late 1940s, Ribeiros had begun to lose population rapidly, and by 1988 at the conclusion of this study there were some 25 residents, mostly over 60 years old. Refer to Caldas (1981), Serrao (1982), and Brettell (1986) for a discussion of possible reasons for the near universal demise of northern, interior Portuguese villages since the 1940s.

In the 1980s, preindustrial agricultural technology was still practiced, if incompletely, by some of the residents of the villages of the Pracais valley, where I visited briefly in 1980, 1983, and 1984. The steep hillsides surrounding Ribeiros are covered with terraces, some of which may have been originally built over 400 years ago when residents and place names in Ribeiros are first mentioned in church birth records. By the 1980s approximately half of these terraces had been abandoned and about 40% had been planted to apple, fig, and olive within the last decade or so by largely absent owners. The remaining 10% were still in cultivation, mostly in corn, bean, potato, and some rye. In terraces closer to the village, vegetables and herbs are grown. The *mato* is harvested at about one tenth the rate that it was 50 years ago when, according to residents, all terraces were planted with seeds. Because agricultural practices in the village are in decline, much of the *mato* on the surrounding hilltops had not been harvested for varying lengths of time, up to 30 or more years.

I lived in Ribeiros from August until December of 1987. Two married couples among the 21 permanent residents provided me with food and shelter, and introduced and endorsed me to the other residents. This endorsement was essential for any resident to speak freely with me. The residents consisted of eight married couples, no single men, and four to six women who were never married or were widows. Except for the wives of my hosts, the wives of the other six men were essentially not socially accessible to me. Three of the single women would talk readily and accept my help.

During the first two months of my fieldwork, I observed people at work, took samples of soil and vegetation, and with the help of a tape recorder and interpreter, learned the local dialect. During the last three months, I conducted informal interviews on demography, agricultural technology, and economic activities. Typically I spent half of each day talking either repeatedly to the same 13 accessible residents of Ribeiros, or to visitors to the village (nine occasions) or to residents of a nearby village (12 occasions). I talked with people usually as long as they would give me their attention, from a few minutes to often an hour or more. I asked the same things in many different ways on different days of the same people and also of different people. I found that whenever different people talked about the same technical subject, their representations were mutually consistent, never contradictory.

To determine and vouch *mato* species accurately, I collected plants in the *mato* near Ribeiros. These collections were identified at the herbarium of the Estacao Agronomica Nacional (LISE), in Oeiras near Lisboa, and named according to *Nova Flora de Portugal* (Franco 1971, 1984). Voucher specimens were deposited in this herbarium, and at The University of Michigan Herbarium (MICH).

To calculate the diversity and abundance of the species of plants in the *mato* from areas subject to different harvesting regimes, I collected samples of vegetation from four areas (referred to as Areas 1–4) in the *mato*-covered slopes to the north and to the east of Ribeiros. Area 1, located 130 m above, and 1 km from, Ribeiros, has been actively harvested for as long as residents can remember. *Erica arborea* caudex is still taken from here to distill *bagaco.* Area 2 is also still actively harvested, but *E. arborea* caudex has not been taken from it recently. This area is located 150 m above, and about 2 km from, Ribeiros. Areas 3 and 4 contain *mato* vegetation that has never been actively harvested. These areas, located on a nearly level hilltop shoulder, are about 250 m above, and 4 km distant from, Ribeiros. Rye, which grows without irrigation during the cold, wet winter, had been cultivated here but cultivation was abandoned about 30 years ago, largely because of the inconvenient distance of the fields from Ribeiros. *Mato* established spontaneously when this rye plot was abandoned. Area 3 is the eastern part of this shoulder, where above ground *mato* vegetation burned off 8 years ago and has since regenerated. It also contains young pines *(Pinus pinaster),* all less than 8 years old. This pine does not survive fires but grows readily from seed following fires or other disturbance. Area 4 is the western part that did not burn. Its pines and *mato* are approximately 30 years old.

The residents' description of the history of the vegetation in Areas 3 and 4 is corroborated by the age of the pines growing in these areas. Pines grow a swirl of branches from their trunk every year. For at least the first 20 and often up to 30 or 40 years, one can age pines by counting these swirls. Sometimes a few years' swirls will be universally lost by wind or by a bud worm break out that inhibits the growth of swirls. This can be checked by counting growth rings. I cut down a 7-year-old sapling, whose rings and swirls matched.

In Area 1 and Area 2, *mato* is cut on a four-year cycle and had been regenerating for the past four years. Individual caudices regenerate growth 10–20 cm in circumference during four years. Areas 1 and 2 have only five or six abundant species. At the scale of a meter square, relative species abundance varies little throughout these areas. So, from an arbitrary one square meter plot in each of Area 1 and Area 2, all vegetation was cut at about 3 cm above the ground, the approximate height at which it is cut by residents when harvested for use. Plants were sorted by species into plastic bags, and removed the next day to Coimbra where the contents of each bag were dried and weighed.

In Area 3, some plants have grown to three times the size of those in Area 1 or 2. Relative species abundance was quite variable at the scale of a square meter, but became more uniform for areas two or three times as large. For this reason, an arbitrary plot 2 m × 3 m was selected for harvesting. All vegetation was cut as described above and sorted by species. Because of the large amount of vegetation produced on this 6 m^2 plot, the quantity produced by each species was weighed wet in the field and approximately 0.5 kg was sealed wet in a plastic bag and removed the next day to Coimbra, where it was weighed and dried and reweighed to determine percent dry weight.

No vegetation samples were taken from Area 4, but the kinds, sizes, and relative abundances of these very large plants were recorded.

To determine the potential of each *mato* species to enrich the soil with mineral nutrients, each plant species was analysed for levels of minerals, including nitrogen and phosphorous, at the Laboratorio Agricola Quimica Ribelo da Silva in Lisboa.

RESULTS

An account of the history and technology of agriculture in this region, learned as a result of my interviews, archival research, and field observations, was presented above. The results presented here are of three kinds. First, what residents do with and say about the most common species in the *mato* establishes the conspicuous importance of maintaining the biological diversity of *mato* species. Second, the relative abundances of *mato* species measured from plots with different disturbance histories evidences that *Erica arborea* becomes dominant in plots where it is not periodically reduced. Third, the relative abundance among *mato* species of mineral nutrients essential for crops establishes the inconspicuous importance of maintaining the biological diversity of *mato* species for soil fertilization.

TABLE 2.—Above ground accumulation in three areas of *mato*. Dry weight (gm) of accumulation per m² precedes average accumulation per year for each species.

Areas	Area 1		Area 2		Area 3	
Size, age	1 m²	4 yr	1 m²	4 yr	6 m²	8 yr
Species						
Erica arborea	103	26	222	56	1,702	213
Ulex minor	—		347	87	882	110
Genista tricanthos	—		104	26	590	74
Erica cinerea	—		163	41	35	4
Halimium ocymoides	—		12	3	7	1
Lithodora difusa	5	1	—		3	0
Caluna vulgaris	30	8	241	60	63	8
Erica umbellata	256	64	—		—	
Chamaespartum tridentatum	816	204	198	50	—	

Erica arborea is called *mato negral*, which means grey or dark *mato*. Although this study reveals it to be the competitive dominant (Table 2), it is not considered a weed or otherwise undesirable by the village farmers. Its woody caudex is genuinely valued as a fuel, and its foliage is also valued as goat forage and bedding. Like all the harvested *mato*, it is spread over the ground inside the goat houses, where it is enriched by goat urine and excrement before it is finally added to the soil.

Ulex minor is called *tojo branco*, which means white *tojo*, even though it is covered with green leaves and prickers all year long. *Genista tricanthos* is called *tojo negro*, which means black *tojo*. It has green leaves in the winter that fall in the dry season, leaving a dark brown thorn scrub that not even goats will eat. Both *tojos* prick the hands of *mato* harvesters, making harvesting unpleasant and difficult, but these plants are nonetheless harvested, included in goat bedding, and finally buried in the soil. Beyond repeating their preference for *mato negral*, residents did not say why the regeneration organs of *tojo branco* and *tojo negro* are not dug up and burned in stills.

Erica cinerea is called *urze*. It is valued for goat forage, although I rarely saw goats eating it, and highly valued for goat bedding. Except from the thorny *tojos*, there was nothing superficially apparent to set *urze* apart from the other cut *mato* spread on the floor in goat houses.

Halimium ocymoides and *Lithodora difusa* are called *mato* plants by residents, but did not have more specific names that anyone remembered. Neither did residents describe specific uses for them. These species make up a very small percentage of the *mato*.

Caluna vulgaris is called *margarise* by the residents of Ribeiros. This species, one of several known as heather, is common throughout northern Europe as well. In Ribeiros, its floral display in August and September is spectacular. Its prolific nectar production is recognized, and in order to increase the amount of honey

TABLE 3.—Concentration (percent dry weight) of nitrogen (N), and phosphorous (P) in samples of *mato* species from study areas, and in a homogenized sample of old cut *mato* removed from the floor of a room housing goats.

	N	P
Erica arborea	0.86	0.055
Ulex minor	0.64	0.140
Genista tricanthos	1.24	0.101
Erica cinerea	0.64	0.160
Halimium ocymoides	0.59	0.080
Lithodora difusa	0.63	0.096
Caluna vulgaris	0.58	0.098
Erica umbellata	0.90	0.055
Chamaespartum tridentatum	0.48	0.100
Old *mato,* homogenized	1.44	0.377

collected by village bee keepers, *mato* is harvested less frequently during the flowering season of *margarise.*

Erica umbellata is called *negrela,* a diminutive *negral.* Its caudex is not taken for fuel, and it is readily excluded by its more aggressive congener, *E. arborea.* Although *urze* is explicitly recognized, all three *Ericas* are valued as goat bedding.

Chamaespartum tridentatum is called *carqueja* here and over most of northern Portugal. It is highly valued as goat forage. The stems are only slightly lignified, and the goats eat much more of it than of the other *mato* species. Like all harvested *mato,* it becomes part of the goat pen bedding before being added to the soil.

Table 2 presents the total and approximate annual above ground accumulation, in dry weight, of each species at each of Areas 1, 2, and 3. Area 4 was densely dominated by *E. arborea,* which had grown, true to its name, into gnarled trees, 2–3 m high, overtopped with 30-year-old pines.

Table 3 presents concentrations, in percent dry weight, of nitrogen and of phosphorous, in samples of *mato* species collected from the study areas, and in old cut *mato* removed from the floor of a room used to house goats. For both of these plant nutrients, the concentrations vary among the species by a factor of more than 2.5. Nutrient levels are clearly increased in *mato* that has been on the floor where goats are housed.

DISCUSSION

For the last 500 years or more, growth of plants of the *mato* has been essential for the maintenance of soil fertility in the Pracais valley and throughout central interior Portugal. The *mato* species play different and complementary roles to support the lives of the local people. Sugar production, fuel, goat forage, and soil fertility have been mentioned here. Thus, maintaining the species diversity of the *mato* is of genuine, immediate economic value to the residents. Some of their traditional practices can be understood by observing and interviewing the people who employ them. Other dimensions of this understanding are suggested by evidence revealed by the decline or discontinuance of these practices, by experimentation, and by laboratory analysis.

Mato negral is one of the many useful plants of the mato, but its competitive superiority would reduce species diversity if were not somehow controlled. The utility of its caudex (the regeneration organ) as a distilling fuel is the stated reason for digging up caudices every fall, even though the caudex of any *mato* plant would work well in a still fire. Over the past 100 years or more, people may have forgotten that this practice helps maintain *mato* species diversity because, when all the *mato* was being cut and properly managed to maintain both soil fertility and diversity, *mato negral* never had a chance to reveal its dominance. This more ecologically and observationally founded understanding of dominance reduction remains implicit in the traditional preference for *mato negral* caudex as the still fuel. It is much more important to the local economy to practice the appropriate activities at the right time than to explain them objectively as long term ecological phenomena.

The residents of the Pracais valley often do explain their technology in very objective terms and with sound observational bases. Their explanation of irrigation technology and the factors that determine the height, width, and frequency of dry stone retaining walls for cultivated terraces, are two examples. Here, scientific explanations incorporate what people need to do to create and maintain these structures. Thus to participants in this self-sufficient economy, an important part of the utility of an explanation is to help people remember what to do.

Results of this study provide two other examples of local distinctions or explanations that seem to serve primarily to instruct people what to do or value, but that also have compelling scientific explanations of longer term effects. The naming of the three different species of *Erica* that occur in the *mato* provides one example. All three *Ericas* look similar enough to be considered congeners by taxonomists; indeed two of them, the large and small *negral*, are given similar names by residents even though they must be distinguished when it is time to distill *bagaco.* Residents give *urze, Erica cinerea,* separate folk generic status and value it highly as goat bedding, even though they give no compelling reasons. When the cut branches of *urze* are spread on the floor of the goat pen with those of other *mato* species, they cannot be readily distinguished and the goats do not seem to treat them differently. Residents do not know that *urze* branches, in comparison to those of the other *mato* species, have the highest phosphorous concentration. As Table 3 shows, *urze* has more than twice the phosphorous of most other *mato* species (only *Ulex minor* has comparable, but lower, levels), and three times the phosphorous of the other two *Ericas.* Because traditional practice is to use and value this species for goat bedding, which ultimately becomes soil enrichment, soil phosphorous levels are more effectively maintained. The ancient sedimentary ilite minerals in the shale-derived soils of central interior Portugal are especially poor in phosphorous and rich in iron (Azevedo and Ricardo 1973). Iron tends to chelate phosphorus so that it can not be taken up by plants. The release of phosphorous from decaying organic matter occurs at a slow enough rate that it can be taken up immediately by growing crop plants and not lost to the iron in the soil. Thus, organic matter has probably always been an essential source of phosphorous for this agricultural system. It is not surprising that hundreds of years of agricultural tradition in this region has distinguished the plant that is the best organic source of phosphorous from other members of its genus, and valued it as goat bedding, even though as goat bedding per se it has no special value.

The second example of an explanation that seems not to have an observational basis, but that is preferred by villagers because it helps people remember what to do, is provided by the concept of the goats' bed. Like valuing *urze* for goat bedding and removing occasional *Erica arborea* caudices for still fires, the important consequence of spreading *mato* as goat bedding is not immediately apparent, and so an explanation that requires the appropriate activity is created. Residents spent about a quarter of their total economic effort cutting *mato,* hauling *mato,* spreading it out in goat pens to make a "bed" for goats, removing it from goat pens, piling it in heaps, and finally carrying it to cultivated terraces to dig into the soil before a new crop is planted. Although this effort is essential for the maintenance of soil fertility, it was always explained primarily as providing food or a bed for goats. Goats feed as foragers grazing at large during the day, and on weeds and thinnings pulled from the cultivated terraces and given to them, along with occasional rations of grain, when they return to their pens in the evening. Except for *carqueja,* the goats ate very little of the cut *mato,* all of which was spread out below them to make their "bed." Even *tojo negro,* leafless, spiny wands of dense wood that goats won't eat, is included in this "bed." The goats stand up, rarely lying on their thorny bed of sticks and twigs. Why is cutting and carrying *mato* explained as a means of providing food and bedding for goats, when residents are fully aware that their goats eat very little of it and rarely lie on it? Why is it not explained as a means of maintaining soil fertility, the need for which the residents are also fully aware? Spreading *urze, tojo negro,* and the rest of the cut *mato* in goat pens before adding it to the soil raises the ratio of nitrogen to carbon in cut *mato* (Table 3). When this old cut *mato* is buried in soil, the higher N/C ratio provides a microenvironment in which the balance of microbes is shifted towards more effective decay organisms that can decompose *mato* and release its nutrients during one growing season (Griffin 1972). In fact, no residual sticks or twigs were evident in the soil at the time of the corn harvest even though 7–10 metric tons dry weight per hectare of *mato* (mostly sticks and twigs) had been added at the time of corn planting. Effective, rapid decay of the dense woody branches of *Genista tricanthos,* which might otherwise decay more slowly than the fruticose twigs of some other *mato* species, is especially important because this species is highest in nitrogen, substantially higher than other species of *mato* (Table 3). Thus it is important for soil fertility to leave the caudices of the slow growing *tojo negro* in the ground, to include its dense, spiny branches in the harvest of cut *mato,* and especially to spread them out in the goat pens. Chemical analyses and microbial ecology are not evoked by residents to explain why they include inedible thorns in the "food" and "bed" of goats, but the consequences of their traditional agricultural practices are clear. Feeding and bedding goats is an explanation that reminds farmers what to do next, especially when the long term consequences of the activity are important, but not immediately apparent. This more proximal, but apparently less correct explanation, thus may serve a self-sufficient village economy better than would a more ultimate, and apparently more correct, one.

Other authors have discussed aspects of some of the ideas presented here. Brush (1986) documents the maintenance of the biological diversity of surrounding areas by farmers practicing traditional methods. Brush (1992) also discusses the specific case of the persistent, deliberate maintenance within individual fields of high potato cultivar diversity by Andean farmers even following the introduction and acceptance of new potato varieties bred by Green Revolution techniques. He lists some of the reasons why farmers might preserve this diversity: taste, interest, agronomic factors, economic opportunity, and prestige or social status, and observes that not a single ecological reason was given by farmers. Zimmer (1991) also discusses the maintenance within individual fields of high potato cultivar diversity by Andean farmers who have *not* accepted Green Revolution varieties, and describes prestige or social status as the most compelling proximal motive. Although neither author demonstrates, or even hypothesizes, a long term ecological effect of the maintenance of high potato cultivar diversity beneficial to these self-sufficient agricultural economies, attributing proximal prestige to those who maintain diversity would stimulate the practice and produce the ultimate benefit, if it did exist.

There are many examples of the use of specific foods or medicines where the preventative or healing effects are known by practitioners who cannot explain, in scientific physiological or chemical terms, how they work. Kuhnlein (1981), Johns (1981), and Timbrook (1987) provide examples. Even though explanations for these practices may incorporate spiritual or magical concepts, by and large these food and medicinal practices are efficacious and people *do* understand the basic purpose for them, namely to maintain or restore health. These authors do not give examples of less relevant or somewhat artificial reasons, such as the examples of bedding goats or choosing still fuel discussed here, that maintain advantageous practices because they evoke appropriate activity.

Concepts of utilitarian explanations and distinctions have been explicitly discussed by some authors. Alcorn (1981), in discussing Huastec perception of botanical resources, mentions invisible technology that not only enables plant use but also manages the plant resource, but gives no examples. Invisible technology may refer to parts of Huastec explanations with little or no observational basis that function to stimulate timely activity, with long term resource management effects not accounted for by the explanation.

Hays (1982) suggests that distinctions among kinds of organisms made in self-sufficient agricultural economies may result in differential behavioral or attitudinal responses to the organisms distinguished with consequences that are useful or beneficial, even when the benefit cannot be described by those making the distinction. If the distinction is made, then the benefit is enjoyed, not because of the explanation but because of the behavior it elicits. The distinction of the phosphorous rich *urze,* whose name differs from *neqral* and *negrela,* the other two *Ericas,* would seem to be an example of this phenomenon.

The procedural, ritualized, unsubstantiated, or seemingly irrelevant explanations that elicit timely or appropriate behavior in self-sufficient farming communities may describe practices that represent a deeper ecological or natural wisdom. The wisdom of these practices (if not of their explanations) may transcend the short term, production orientation of modern agricultural technology, whose development has been in part motivated by the desire to convert natural resources to cash profits as fast as possible. It is becoming clear that many modern agricultural practices cannot be sustained without decimating the very natural resources on which productivity depends. Studying, recording, and understanding the human ecosystem in the Pracais valley, an ecosystem based on practices that for centuries have sustained agricultural production on poor soils, is especially relevant to the present challenge of developing technology for sustainable agriculture to ensure the future well-being of people. Some aspects of this preindustrial technology were still available through the memory and activities of the aging residents of the Pracais valley. However, some access to the understanding of how things worked, and especially why things worked, is made available to us by studying the present breakdown of their traditional system. For these reasons, studies of preindustrial agricultural systems should be undertaken with any available evidence of how and why these past technologies were successful.

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BOOK REVIEW

Histoire Illustreé du Caoutchouc. Jean-Baptiste Serier, Antionette Diez, and Anne Van Dyk. France: Montpelier Cedex 1 (CIRAD-CP, BP5035, 34032), 1993. $27.00 U.S. (167 French Francs). (No ISBN found)

It is almost impossible to "review" this extraordinary and unusual book because it depicts the story of rubber in 96 pages of illustrations. The 450 pictures record the history of rubber from the dinosaur age and that of early man through the use of the product in pre-conquest Mexican times to the "discovery" by Europeans, the early periods of the tapping of *Hevea* through to the beginnings of commercialisation of Amazonian rubber production to the introduction of *Hevea brasiliensis* to Asia and the establishment of the plantations in the Old World tropics.

The book, extremely novel in its approach, should be useful in teaching economic botany courses and will certainly be of interest to general audiences.

The artist-authors are to be congratulated for making available such an interesting detailed illustrated history of rubber, its uses, and commercial aspects of its development.

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